ZooKeys 1180: 317–332 (2023)
DOI: 10.3897/zookeys.1180.105233

Research Article

A new species of torrent catfish, *Liobagrus geumgangensis* (Teleostei, Siluriformes, Amblycipitidae), from Korea

Su-hwan Kim[1], Seung-woon Yun[2], Jong-young Park[2]

1 *National Institute of Ecology, Seocheon 33657, Republic of Korea*

2 *Department of Biological Sciences, College of Natural Sciences, Jeonbuk National University, Jeonju 54986, Republic of Korea*

Corresponding authors: Jong-young Park (park7877@jbnu.ac.kr); Seung-woon Yun (ysw0314@jbnu.ac.kr)

Abstract

In a recent survey of populations of the Korean torrent catfish *Liobagrus*, a distinctive species was discovered from the Geum River and its tributaries flowing into the western coast of Korea, and here described as a new species, *L. geumgangensis* **sp. nov.** It is distinguishable from other congeners by a combination of the following characters: I, 8 pectoral fin-rays; 52–56 caudal-fin rays; a relatively short occiput to dorsal-fin origin distance (6.9–9.8% SL); a short pelvic-fin insertion to anal-fin origin distance (11.9–17.3% SL); a long dorsal-fin base (10.6–13.5% SL); 8–9 gill rakers; 5–8 serrations on the pectoral fin; the body and fins are dark yellow, the margins of the dorsal, anal, and caudal fins are dark brown, but the outermost rim is faintly yellow. Analysis of the cytb gene also confirmed that *L. geumgangensis* is a monophyletic lineage distinct from other congeners.

Key words: Catfishes, cytb, DNA, geographical speciation, key, morphometrics, taxonomy

OPEN ACCESS

Academic editor: Yahui Zhao
Received: 20 April 2023
Accepted: 1 September 2023
Published: 26 September 2023

ZooBank: https://zoobank.org/E8E5FF0F-2330-4EE5-A634-3C508B8545C6

Citation: Kim S-h, Yun S-w, Park J-y (2023) A new species of torrent catfish, *Liobagrus geumgangensis* (Teleostei, Siluriformes, Amblycipitidae), from Korea. ZooKeys 1180: 317–332. https://doi.org/10.3897/zookeys.1180.105233

Copyright: © Su-hwan Kim et al.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

The family Amblycipitidae, which includes four genera (*Liobagrus* Hilgendorf, 1878; *Amblyceps* Blyth, 1858; *Xiurenbagrus* Chen & Lundberg, 1995; *Nahangbagrus* Nguyen & Vo in Nguyen 2005), is restricted to southern and eastern Asia, including Pakistan (*Amblyceps*), and across northern India (*Amblyceps*) through Myanmar, Laos, Cambodia, Thailand to Malaysia (all *Amblyceps*), Vietnam (*Nahangbagrus*), China (*Amblyceps*, *Liobagrus*, *Xiurenbagrus*), Korea (*Liobagrus*), and southern Japan (*Liobagrus*) (Chen and Lundberg 1995; Ng and Kottelat 2000; Kim and Park 2002; Wright and Ng 2008; Park and Kim 2010; Kim et al. 2015; Chae et al. 2019).

Genus *Liobagrus* can be distinguished from the genus *Amblyceps* by its pale fin margins, adipose fin confluence with the caudal fins, rounded or truncated caudal fin (Wright and Ng 2008), and main distribution in eastern Asia. Including the most recently described species, *L. brevispina*, 14 species have been reported from the Yangtze River (Changjiang) in mainland China, five species from Korea, and one species from Japan, for a total of 20 species. *Liobagrus* from the Korean Peninsula have been described with the following characteristics: *L. andersoni* Regan, 1908c, is distinguished by upper and lower jaws of equal length; *L. mediadiposalis* Mori, 1936, by a shorter lower than upper jaw; *L. obesus* Son, Kim & Choo, 1987 by fewer serrations on the pectoral fin; *L. somjinensis* Park &

Kim, 2010, by the broad yellowish, vertical, crescent-shaped band in the middle of the caudal fin; and *L. hyeongsanensis* Kim, Kim & Park, 2015 by its small size, with a maximum standard length of 90 mm, and body and fins that are entirely yellowish brown without distinct markings.

The Korean Peninsula is largely divided into western and eastern halves by the Baekdudaegan Mountain Range. Recent studies on freshwater fish from Korea have focused on taxonomic reviews of fish separated by this range: *Koreocobitis rotundicaudata* (West), Wakiya and Mori 1929 vs. *K. naktongensis* (East), Kim et al. 2000; *Coreoleuciscus splendidus* (West), Mori 1935 vs. *C. aeruginos* (East), Song and Bang 2015; *Cobitis nalbanti* (West), Vasil'eva et al. 2016 vs. *C. hankugensis* (East), Kim et al. 2003. Following this logic, it is suspected that subpopulations of *L. mediadiposalis*, which are widely distributed across river drainages from the western (Geum River) to the southeastern (Nakdong River) portions of South Korea, may actually represent distinct species (Son 1987; Kim et al. 2006; Kim 2013). In this study, we investigate the identity of *L. mediaposalis* from the Geum River and confirm its distinctiveness from *L. mediadiposalis* s. str., describing it here as *Liobagrus geumgangensis*, a new species.

Materials and methods

Morphological analysis

All samples were collected using a scoop net, fixed in 10% formalin, and preserved in 80% ethanol. Count and measurement procedures were taken following Hubbs and Lagler (1964) and Wright and Ng (2008). Fin spines and soft rays were counted from radiographs and bone staining, and the last two elements of the dorsal and anal fins were counted as one ray. Vertebral counts were also made from soft X-ray radiographs (HA80, HITEX), and the three components associated with the Weberian apparatus were excluded (Chen and Lundberg 1995; Zhao et al. 2004). Gill raker counts were made on the left side on the upper limb of the first arch with an additional 20 specimens to avoid damage to the holotype and paratype specimens (see Comparative material examined). Caudal fin-ray counts include principal caudal-fin rays and dorsal and ventral procurrent caudal-fin rays. Measurements were taken using digital calipers (0.01 mm) and expressed as standard length (**SL**) percentages in Table 1 which included data, followed by the number observed for each count and measurements in parenthesis. All Korean specimens are deposited in the Faculty of Biology at Jeonbuk National University, Jeonju, Korea (**CNUC** herein; current acronym is **JNUC**). Other specimens were used as those deposited in the following institutions: Institute of Zoology, Chinese Academy of Sciences (**CAS**); Institute of Hydrobiology, Chinese Academy of Sciences (**IHB**); National Tsing Hua University (**NTHUB**). Counts and measurements for all paratypes, if different from the holotype, are presented in parentheses after the value for the holotype.

DNA analysis

For genomic DNA analysis, a piece of pectoral fin was dissected from the specimen and stored in 100% ethyl alcohol. Next, total DNA was extracted with the genomic DNA Prep Kit for blood and tissue (QUIAGEN Co., USA). The

Table 1. Morphometric data of *Liobargus geumgangensis* sp. nov.

Morphometrics	Holotype	Paratype (*N* = 20)		
		range	mean	SD
Standard length (mm)	70.7	57.0–88.3	73.8	9.3
In percentages of standard length				
Preocciput length	23.0	19.8–24.2	21.8	1.2
Predorsal length	30.7	27.3–31.5	30.1	1.1
Prepectoral length	21.5	18.8–23.4	21.6	1.1
Prepelvic length	44.7	42.7–47.4	45.6	1.4
Distance from occiput to dorsal-fin origin	9.1	6.9–9.8	8.0	0.7
Distance from pectoral-fin origin to dorsal-fin origin	14.7	14.0–16.0	15.0	0.6
Distance from pectoral-fin origin to pelvic-fin origin	24.6	23.3–30.3	27.1	1.7
Distance from dorsal-fin origin to pelvic- fin origin	22.9	21.6–28.1	25.1	1.7
Distance from pelvic-fin origin to adipose- fin origin	16.5	14.8–21.6	18.0	1.4
Distance from pelvic-fin origin to anal-fin origin	14.8	11.9–17.3	14.5	1.4
Anal-fin base length	18.3	16.4–20.4	18.8	1.0
Dorsal-fin base length	12.1	10.6–13.5	11.8	0.8
Occiput to pectoral-fin origin	12.5	10.9–14.3	12.5	1.0
Interorbital width	8.6	6.2–8.5	7.4	0.6
Body width at pectoral-fin origin	17.4	16.2–19.4	17.7	0.9
Body width under dorsal-fin origin	15.2	13.8–17.2	15.6	1.0
Head width	21.7	18.0–22.0	19.6	1.3
Pectoral spine length	9.7	7.9–10.8	9.8	0.7
Dorsal spine length	8.9	6.9–9.7	8.6	0.7
Caudal-fin length	21.0	16.3–21.3	18.7	1.2
Maxillary-barbel length	23.6	17.8–26.9	22.7	2.4
Nasal-barbel length	18.4	14.1–18.9	16.3	1.6
Outer-mental barbel length	13.4	10.0–16.2	13.2	2.0
Inner-mental barbel length	9.6	7.4–11.2	9.1	1.2

mitochondrial cytochrome b gene was amplified by PCR using the method of Kim et al (2006): forward (F- 5' ACCACCGTTGTHNTTCAACTA 3') and reverse primer (R- 5' TAGAATYYTRGCTTTGGGAG 3'). PCR reactions were completed in a total volume of 50 µl, consisting of 2 µl genomic DNA, 1 µl of the 10 µM forward and reverse primer solutions, 24 µl of Premix Taq (Takara, Japan), and 22 µl of distilled water (Takara, Japan). PCR for all specimens was executed in GeneAtlas G-02 thermocycler (Astec, Japan) with initial denaturing step at 94 °C for 2 min and 30 cycles of 45 s at 94 °C, 1 min at 52 °C, and 1 min at 72 °C. A final extension step at 72 °C for 5 min. The PCR amplicons were visualized on a 2% agarose gel stained with LoadingStar (Dyne, Korea) together with negative controls and Takara 1 kB molecular size ladder for preliminary size determination. The final PCR products were run on an ABI-3730XL sequencer (Applied Biosystems, USA).

Molecular analysis was performed using the cytochrome b (cytb) sequences of seven newly obtained populations of *L. geumgangensis*, and data from 36 other Siluriformes specimens, including the genus *Liobagrus*, which are closely related. Sequence data of species other than *L. geumgangensis* were downloaded from the National Center for Biotechnology Information (NCBI) GenBank (Table 2). After aligning, the obtained genetic information through Clustal

Table 2. List of mitochondrial cytb sequences newly obtained in this study and downloaded from GenBank with information on collection sites in South Korea and country of origin.

Species	Location of voucher specimens	GenBank Accession No.	Remarks in Fig. 5
Ameiurus catus	USA	MG570433	
Ameiurus melas	China	KT804702	
Ameiurus natalis	USA	MG570406	
Hemibagrus guttatus	China	KJ458934	
Hemibagrus macropterus	China	JF834542	
Hemibagrus nemurus	Malaysia	KJ573466	
Hemibagrus spilopterus	Cambodia	JQ343983	
Horabagrus brachysoma	India	KU870467	
Ictalurus furcatus	USA	KM576102	
Ictalurus pricei	Mexico	KJ496298	
Leiocassis crassilabris	China	JX867257	
Liobagrus andersoni	South Korea	NC032035	
Liobagrus anguillicauda	China	JQ026256	
Liobagrus geumgangensis	South Korea (Cheongyang)	OP980981 (this study)	1
	South Korea (Gongju)	OP980982 (this study)	2
	South Korea (Boeun)	OP980984 (this study)	3
	South Korea (Youngdong)	OP980985 (this study)	4
	South Korea (Muju)	OP980983 (this study)	5
	South Korea (Jinan)	OP980986 (this study)	6
	South Korea (Gosan)	OP945750 (this study)	7
Liobagrus hyeongsanensis	South Korea	MZ066608	
Liobagrus kingi	China	KC193779	
Liobagrus marginatoides	China	KC473938	
Liobagrus marginatus	China	NC022923	
Liobagrus mediadiposalis	South Korea	KR075136	
	South Korea (Sancheong)	OP980987 (this study)	8
Liobagrus nigricauda	China	KC316116	
Liobagrus obesus	South Korea	DQ321752	
Liobagrus reini	Japan	AP012015	
Liobagrus somjinensis	South Korea	MN756661	
Liobagrus styani	China	KX096605	
Noturus taylori	USA	KP013089	
Ompok bimaculatus	India	KY887474	
Ompok pabda	Bangladesh	MK007074	
Pelteobagrus eupogon	China	KJ001784	
Pelteobagrus fulvidraco	China	HM641815	
Pelteobagrus nitidus	China	HM746659	
Silurus asotus	China	JX087351	
Silurus lanzhouensis	China	JF895472	
Silurus meridionalis	China	HM746661	
Silurus microdorsalis	South Korea	KT350610	

Omega (total 1138 bp), Mega X was used to prepare genetic distance and maximum likelihood (ML) trees (with GTR+G+I model). Bootstrap assembling was performed with 1000 replications with rapid options.

Results

Amblycipitidae Day, 1873

***Liobagrus geumgangensis* sp. nov.**
https://zoobank.org/30082398-3DD5-4F22-B58D-E340E9CF38DE
Figs 1–5, Tables 1–3

Type locality. Geum River, Korea.

Type material. ***Holotype*.** CNUC 39103, 70.7 mm SL, male, Geum River, Namyang-myeon, Cheongyang-gun, South Korea. 36°23'41.66"N, 126°48'41.30"E, collected by J.Y. Park, S.W. Yun and H.T. Kim using a scoop net, 14 March 2018 (Fig. 1). ***Paratypes*.** CNUC 39102, 39104–39113, 39129–39137 (20), 57.0–88.3 mm SL, same data as holotype.

Diagnosis. *Liobagrus geumgangensis* can be distinguished from other species in the genus by the length of the upper and lower jaws, and the presence or absence of serrations on the posterior edge of the pectoral fin, which are representative characteristics of the genus *Liobagrus*. *Liobagrus geumgangensis* has a longer upper than lower jaw and serrations on the posterior edge of the pectoral fin. Species that share these characteristics with *L. geumgangensis* are as follows: *L. mediadiposalis*, *L. somjinensis*, *L. hyeongsanensis*, *L. huaiheensis* and *L. pseudostyani*. This new species can be distinguished by the relatively large number of serrations (5–8) on the posterior edge of the pectoral fin (vs. 4–6 in *L. mediadiposalis* and *L. somjinensis*, 2–3 in *L. hyeongsanensis*, *L. huaiheensis* and *L. pseudostyani*). It can be further differentiated from *L. huaiheensis* and *L. pseudostyani* by the subtruncate caudal fin (vs. rounded). *Liobagrus geumgangensis* is distinguished from its geographically closest congeners *L. mediadiposalis* and *L. somjinensis* by the following combination of characteristics: the body and fins are dark yellow, and the margins of the dorsal, anal, and caudal fins are dark brown, but the outermost rim is faintly yellow (vs. broad yellowish outer margin of the fins in *L. mediadiposalis* and crescent-shaped band in the middle of the caudal fin in *L. somjinensis*); pectoral fin rays I, 8 (vs. both I, 7); caudal fin rays 52–56 (vs. both 57–61); a relatively short occiput to dorsal-fin origin (6.9–9.8% SL vs. 10.3–13.3% in *L. mediadiposalis* and 9.7–13.0 in *L. somjinensis*); a short pelvic-fin origin to anal-fin origin (11.9–17.3% SL vs. 15.3–20.9% in *L. mediadiposalis* and 13.3–18.7% in *L. somjinensis*); a long dorsal-fin base (10.6–13.5% SL vs. 7.7–10.4% in *L. mediadiposalis* and 8.8–11.3% in *L. somjinensis*); and 8–9 gill rakes (vs. 7–11 in *L. mediadiposalis* and 7–9 in *L. somjinensis*) (Figs 1, 2).

Description. Counts and measurements, expressed as percentages of SL, are given in Table 1. Dorsal fin II, 6 (21); origin closer to snout tip than anal-fin origin, posterior margin convex. Dorsal-fin spine equal to or a little shorter than pectoral-fin spine. Adipose fin long, well developed, reaching to or slightly exceeding anal-fin base, confluent with caudal fin, margin convex. Adipose fin depth relatively low. Pectoral fin I, 8 (21); origin anterior to vertical through posterior margin of operculum, partially covered by opercular membrane. Pectoral-fin spine slightly sharp and long, with 4 (4), 5 (8) or 6 (9) serrations on posterior edge. Pelvic fin i, 5 (21); short, located at vertical through, or occasionally slightly anterior to adipose fin; tip not connected to base of anal fin. Anal fin with 14 (1), 15 (2), 16 (9), 17 (7), or 18 (2) rays; distal margin rounded, short, origin placed slightly posterior to vertical through adipose fin origin, posterior

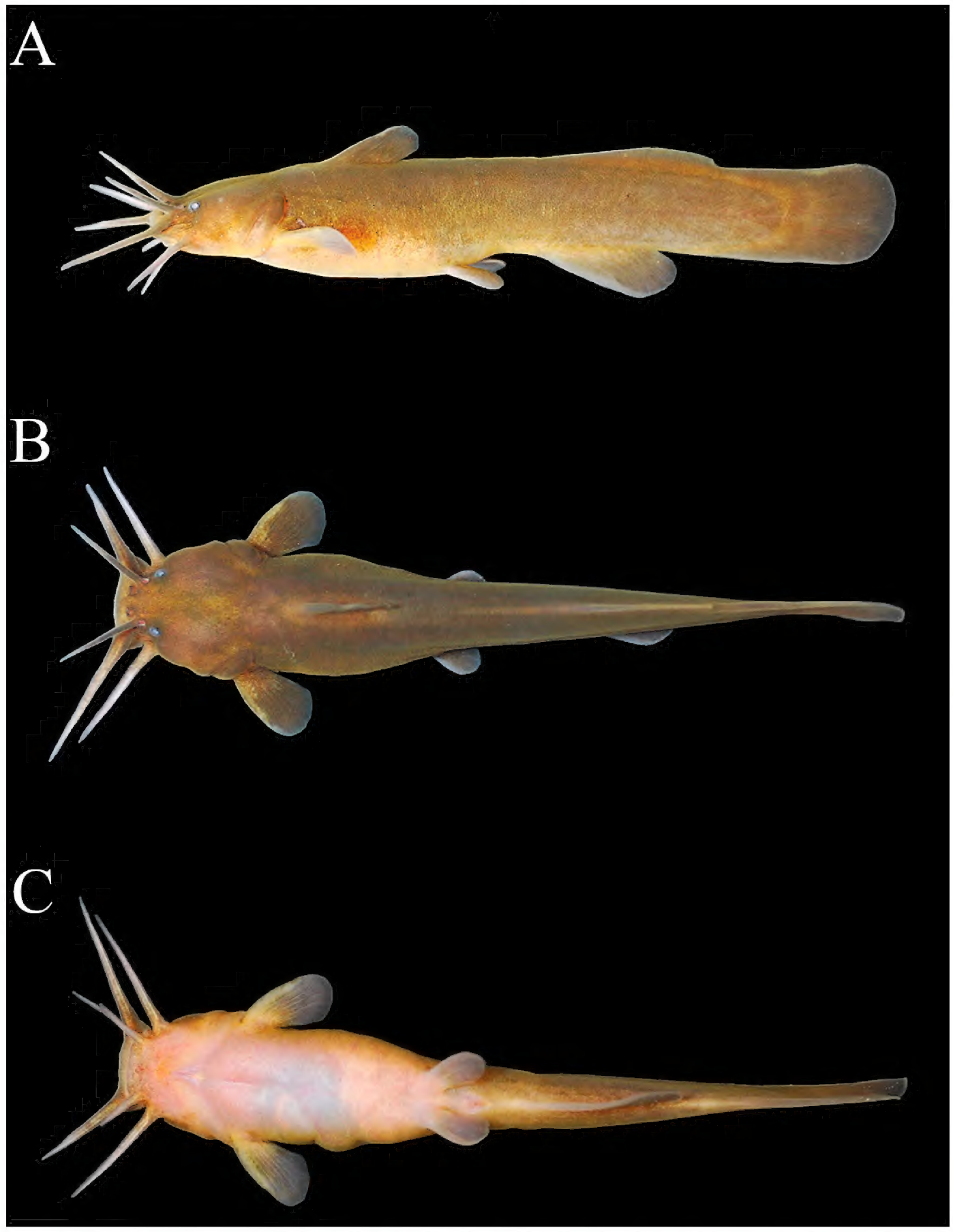

Figure 1. *Liobagrus geumgangensis* sp. nov. holotype (CNUC 39103), 70.7 mm SL, male, Geum River, Namyang-myeon, Cheongyang-gun, South Korea; lateral (**A**), dorsal (**B**) and ventral (**C**) views.

tip of anal fin not exceeding posterior margin of adipose fin. Caudal fin subtruncately rounded with 52 (3), 54 (5), 55 (3), or 56 (10). Vertebrae with 38 (9), 39 (8), or 40 (4) post-Weberian elements. Gill rakers 8–9.

Mouth terminal; lips thickened and papillate, premaxillary and mandibular toothpads curved, teeth small and ciliform or setiform, with upper jaw slightly longer than lower jaw. Four pairs of barbels; maxillary barbel longest, reaching to base of pectoral-fin spine; nasal barbel short, not reaching to posterior margin of preoperculum; outer mental barbel long, reaching to posterior edge of pectoral-fin base; inner-mental barbel shortest among four pairs of barbels, about half length of outer mental barbel, reaching to gill membrane. Body compressed and round, head depressed and caudal peduncle strongly compressed; dorsal and ventral profiles straight. Predorsal profile slightly sloping ventrally from dorsal fin to occiput. Eye smaller, dorsolateral, subcutaneous, ovoid. Snout rounded in dorsal view. Anterior nostril tubular, rim with a fleshy flap forming a short tube;

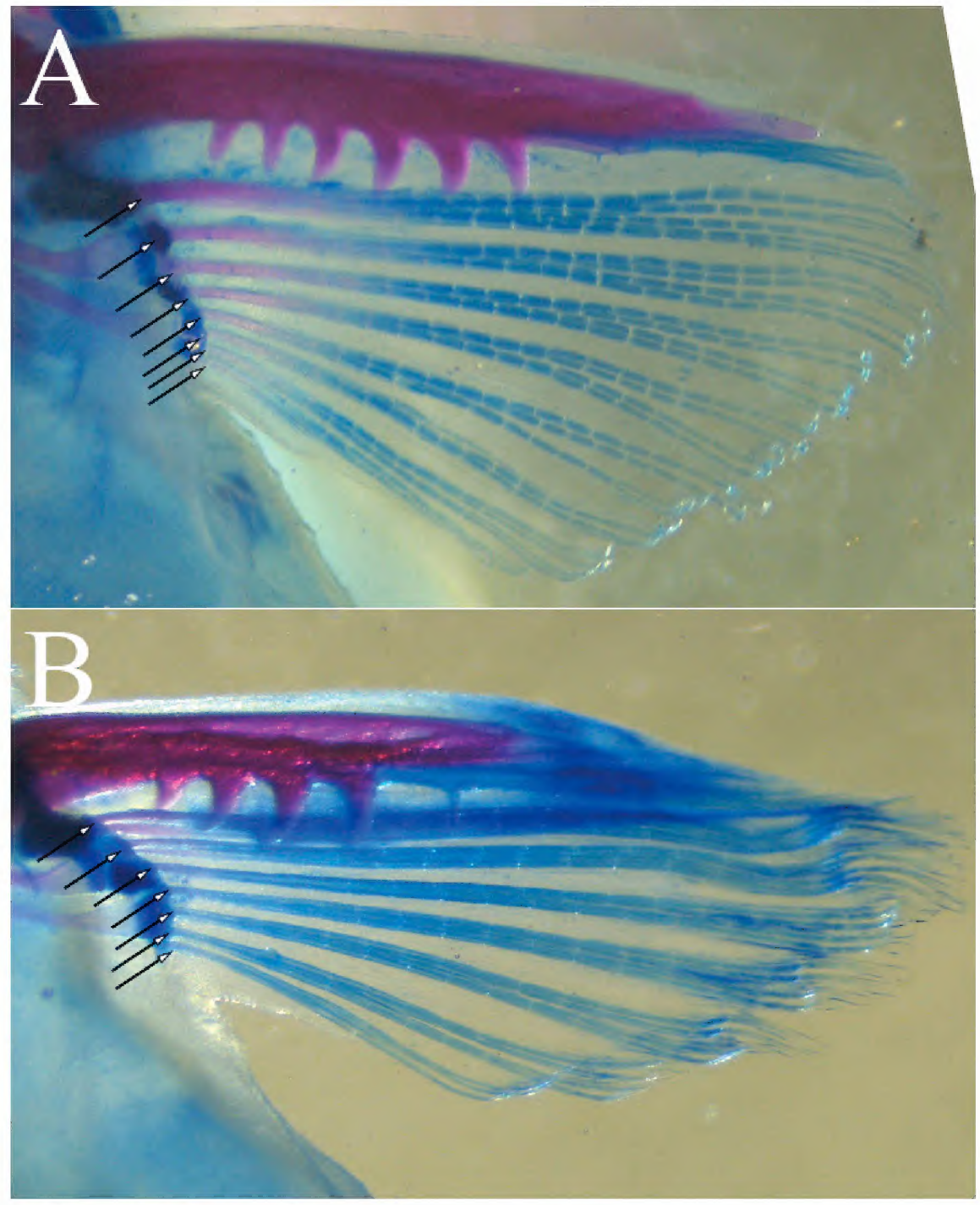

Figure 2. Comparison of pectoral-fin spines and rays of *Liobagrus geumgangensis* (**A**) and its congener *L. mediadiposalis* (**B**) **A** CNUC 38919, 87.8 mm SL, Geum River, Cheongyang-gun, South Korea **B** CNUC 38930, 77.5 mm SL, Nakdong River, Sancheong-gun, South Korea.

posterior nostril porelike, rim posteriorly confluent with base of nasal barbel. Gill membranes narrowly joined at isthmus. Lateral line absent or vestigial.

Coloration. See Fig. 1 for general appearance. In life (Fig. 1): body generally brownish yellow, fading to light yellow on ventral surface, without any distinct markings. All barbels pale gray. All fins with similar color to body, without deep yellow outer margins.

Sexual dimorphism. The adductor mandibulae in males is somewhat swollen during the spawning season, from late April to June.

Etymology. Named after the Geum River (Geumgang in Korean), the type locality. We propose the Korean name Geumgang-Jagasari for this species.

Distribution. *Liobagrus geumgangensis* sp. nov. is restricted to some rivers flowing to the west coast of South Korea: Geum River and upper stream of Mangyeong River (Fig. 5).

Biology and habitat. *Liobagrus geumgangensis* is nocturnal and benthic. They inhabit the bottom stratum of large and small stone or pebble substratum in shallow waters, about 0.3–0.6 m deep, with running waters with moderately fast currents. The spawning season is from late April to June. The adult females reach up to 99.8 mm SL and lay eggs 2.5–3.0 mm (2.8±0.1) in diameter. The adult males guard their fertilized egg. They feed mostly on aquatic insect larvae such as those of the Trichoptera, Ephemeroptera and Diptera.

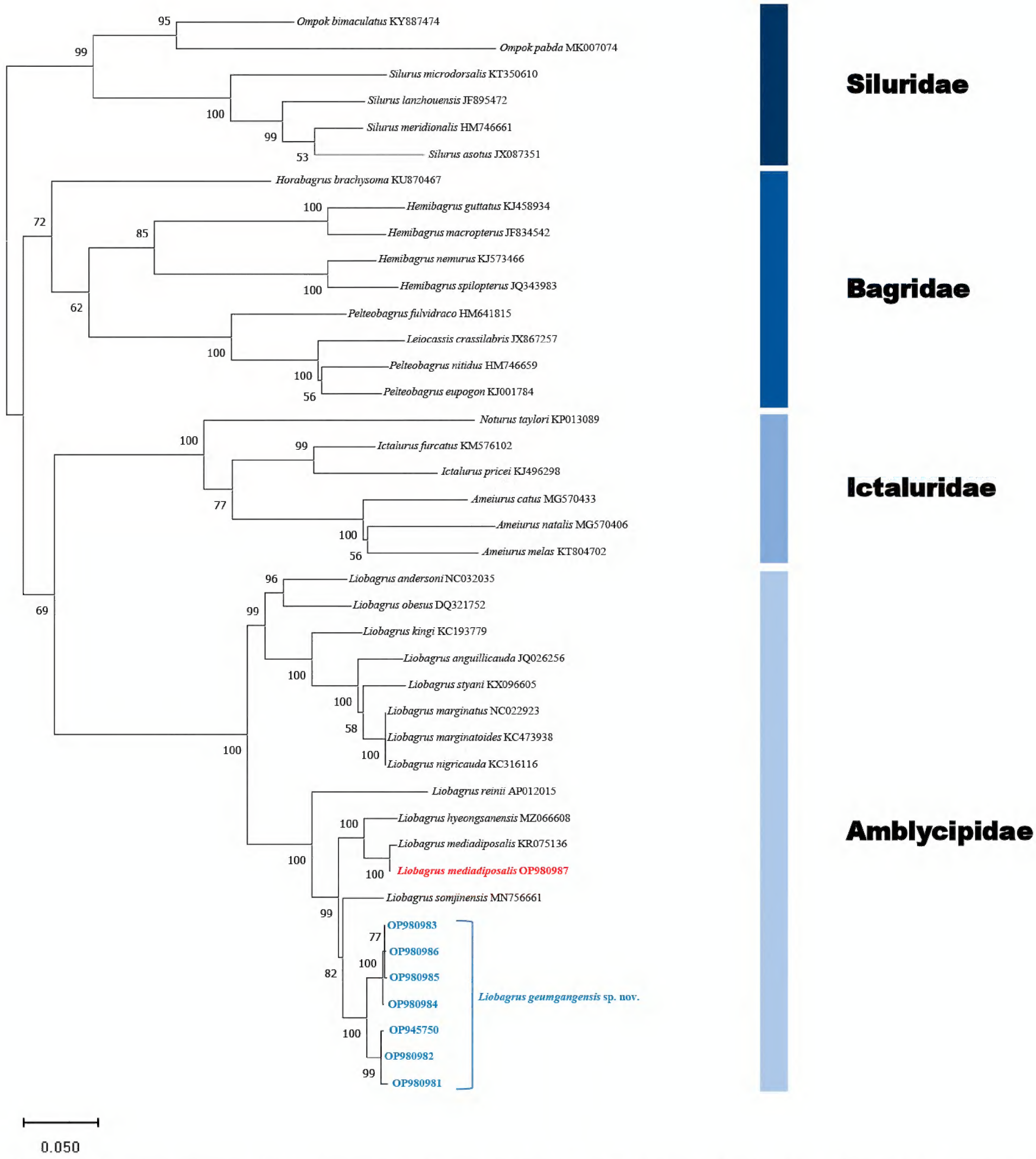

Figure 3. Phylogenetic tree using maximum likelihood (ML) method based on mitochondrial cytochrome b gene sequences of Siluriformes species including *L. geumgangensis*. Bootstrap support values based on 1000 replicates are displayed on each node as >50. The blue color of the branches indicates *L. geumgangensis*.

Molecular analysis

As a result of the cytb gene analysis, we confirm that samples from *Liobagrus geumgangensis* form an independent group distinct from the closely related species *L. mediadiposalis* and *L. somjinensis*. Kimura's 2-parameter distance analysis revealed genetic distances ranging from 0.2% to 2.3% within groups of *L. geumgangensis* populations. We found the genetic distance between

Figure 4. *Liobagrus mediadiposalis* (**A**), CNUC 39153, 97.0 mm SL; male, Nakdong River, Sancheong-gun, South Korea and *L. somjinensis* (**B**), CNUC 39170, 99.4 mm SL, male, Somjin River, Namwon-si, South Korea.

Figure 5. South Korea, showing distributions of *Liobagrus geumgangensis* (1–7), *L. somjinensis*, *L. hyeongsanensis*, and *L. mediadiposalis*. Dark green line: Baekdudaegan mountain range, showing three biogeographical ranges of ichthyofaunal endemism on the Korean Peninsula (modified from Kim 1997).

L. geumgangensis and *L. somjinensis* to be 4.7% to 5.0%, which was smaller compared to that observed with *L. mediadiposalis* (5.8% to 6.1%; Fig. 4). These findings provide robust evidence that *L. geumgangensis* is rather genetically close to *L. somjinensis*, while suggesting that it is a distinctly different species from congeneric species.

Table 3. Comparisons of major diagnostic characters of *Liobagrus* species distributed in Korea and neighboring countries.

Character	*L. geumgangensis*	*L. mediadiposalis*	*L. andersoni*	*L. obesus*	*L. somjinensis*	*L. hyeongsanensis*	*L. reini*	*L. formosanus*	*L. nigricauda*	*L. marginatoides*
Upper/lower jaw in length	>1	>1	=1	=1	>1	>1	>1	=1	=1	<1
Caudal fin shape	Subtruncate	Subtruncate	Subtruncate	Subtruncate	Subtruncate	Subtruncate	Rounded	Rounded	Rounded	Subtruncate
Number of serrations on the pectoral fin	5–8	4–6	0–3	3–5	4–6	2–3	0	0	0	0
Occiput to dorsal-fin origin	6.9–9.8	10.3–13.3	8.5–12.4	9.4–15.1	9.7–13.0	9.3–12.9	8.3–9.4	7.2–10.2	7.6–13.3	8.8–11.6
Pelvic-fin origin to anal-fin origin	11.9–17.3	15.3–20.9	11.9–17.0	9.6–14.1	13.3–18.7	12.1–16.6	12.7–15.3	13.5–19.1	12.1–16.4	13.6–17.9
Dorsal-fin base length	10.6–13.5	7.7–10.4	10.3–15.2	12.4–16.0	8.8–11.3	7.8–10.9	10.6–12.7	11.0–14.4	6.3–12.0	11.0–14.4
Character	***L. styani***	***L. marginatus***	***L. anguillicauda***	***L. aequilabris***[a]	***L. chenghaiensis***[b]	***L. kingi***[c]	***L. hualheensis***[d]	***L. chengduensis***[e]	***L. pseudostyani***[e]	***L. brevispina***[f]
Upper/lower jaw in length	>1	<1	=1	=1	≤ 1	≤ 1	>1	<1	>1	=1
Caudal fin shape	Rounded	Subtruncate	Rounded	Rounded	Subtruncate	Rounded	Rounded	Rounded	Rounded	Rounded
Number of serrations on the pectoral fin	0	3–4	0	0	2–5	2–4	2–3	3–4	2–3	0
Occiput to dorsal-fin origin	5.8–11.4	8.8–12.1	8.0–10.7	–	–	–	–	–	–	–
Pelvic-fin origin to anal-fin origin	10.3–14.1	12.3–17.2	12.0–14.6	–	–	–	–	–	–	–
Dorsal-fin base length	8.2–12.7	10.8–15.3	8.5–10.7	–	–	–	–	–	–	–

a, Wright and Ng 2008; b, Sun et al. 2013; c, Xie and Zhang 2018; d, Chen et al. 2021; e, Chen et al. 2022; f, Xie et al. 2022.

Discussion

Compared with the original descriptions of *Liobagrus* (Hilgendorf 1878; Gűnther 1892; Regan 1904, 1908a, b, c; Oshima 1919; Nichols 1926; Wu 1930; Tchang 1935; Mori 1936; Son et al. 1987; Wright and Ng 2008; Park and Kim 2010; Kim et al. 2015) and based on coloration and meristic and morphometric data, we confirmed that *L. geumgangensis* sp. nov. is distinct from *L. mediadiposalis*. The number of pectoral fin rays is I, 8 in *L. geumgangensis* (vs. I, 7 in *L. mediadiposalis*) and the number of caudal fin rays is 52–56 (average 54.9) (vs. 57–61). The distance between the occiput and dorsal-fin origin is shorter at 6.9–9.8% SL than *L. mediadiposalis* (10.3–13.3% SL). The relative lengths of the upper and lower jaws are a key characteristic used in identifying *Liobagrus* species, with three possible states identified: lower jaw longer than upper (*L. marginatoides*, *L. marginatus*, *L. kingi*, and *L. chengduensis*), jaws of equal length (*L. andersoni*, *L. obesus*, *L. nigricauda*, *L. anguillicauda*, *L. brevispina*, *L. aequilabris*, and *L. formosanus*), and upper jaw longer than lower (all remaining congeners; Table 3). On the Korean Peninsula, *L. andersoni* and *L. obesus* have jaws of equal length, where-

as *L. geumgangensis*, along with *L. mediadiposalis*, *L. somjinensis* and *L. hyeongsanensis*, have a lower jaw shorter than its upper jaw. *Liobagrus mediaposalis*, *L. somjinensis* and *L. hyeongsanensis* all have I, 7 pectoral-fin rays; just two species, *L. andersoni* and *L. geumgangensis* have I, 8 pectoral-fin rays. The pectoral fin rays are not used as a common diagnostic characteristic and are considered to be species-specific variables, but in contrast, some studies have suggested fixed results (Xie et al. 2022). Since this study did not measure a large number (*N* = 30) of *L. andersoni* specimens, it is possible that the number of pectoral fin rays may vary, but this study intends to use this as a comparative characteristic.

To summarize, within the *Liobagrus* distribution in Korea, it is noteworthy that *L. geumgangensis* is the only species with an upper jaw longer than the lower jaw and I, 8 pectoral fin rays. In addition, *L. geumgangensis* differs from *L. somjinensis* in several characters: absence vs. presence of a broad vertical yellowish crescent-shaped band on the caudal fin, with a deep black outer margin; 5–8 vs. 4–6 serrations on the pectoral fin; and 52–56 caudal fin rays vs. 57–61 (Fig. 4).

Liobagrus geumgangensis is allopatrically distributed in restricted river systems, the Geum River and a patch of the Mangyeong River, which flow toward the western coast of Korea. Unlike other *Liobagrus* species, *L. somjinensis* is restricted to rivers flowing to the west coast and Geogeum Island, the Somjin, Dongin and Tamjin rivers. *Liobagrus hyeongsanensis* has a much smaller distribution including the Hyeongsan River flowing into the east coast, whereas *L. mediadiposalis* is found only in the Nakdong River on the west coast (Fig. 5). *Liobagrus andersoni* is restricted to the Han River system alone. Meanwhile, *L. obesus* has a wide distribution including the western river systems of Geum, Yeongsan and Mangyeong, and their distribution overlaps with other congeners. Interestingly, based on morphological and genetic research, all six species of the Korean *Liobagrus* are endemic (Kim et al. 2006, 2015; Park and Kim 2010; Kim 2013).

Our results are consistent with a recent study by Kim et al. (2006) on the evolutionary relationships among *L. mediadiposalis* populations in Korea using cytochrome b sequences. Kim et al. (2006) considered Type I to be the Somjin River group, which included four populations (Dongin, Somjin, and Yeongsan rivers and Geogeum Island), and Type II as the Geum River group comprising a single population. Although they confirmed that the Geum River group was genetically distinct from *L. mediadiposalis*, the taxonomy of this population was not further investigated. Here, our analysis of seven different populations confirms that the Geum River group represents a distinct, unnamed species (Fig. 3).

The geographical isolation of the freshwater fish of South Korea is likely related to the geological origins of the Korean Peninsula. The Korean Peninsula was formed by active orogeny movements from the early Triassic to the Jurassic. The structure of the current complex topography is due to the tectonic shift concentrated in the Tertiary Period of the Cenozoic Era. As a result, Korea has an approximately 1400 km long mountainous region stretching from North Korea to South Korea. The peninsula, called the Baekdudaegan, contains at least 12 mountain ranges that have formed unique rivers, including the Han, Geum, Nakdong, Hyeongsan, and Mangyeong rivers (Chough et al. 2000; Sohn et al. 2001). Consequently, some Korean freshwater fish are distributed allopatrically, causing speciation.

According to Mori (1936) and Kim (1997), the freshwater fish fauna on the Korean Peninsula is divided into three biogeographical regions: northeast, west, and southern Korea subdistricts. Such biogeographical distributions based on

large mountain ranges creating physical barriers and allopatric distributions lead to endemic species (Fig. 5). In particular, Korean cobitid fishes, including 10 endemic species, are the best example of a diverse regional distribution (Kim and Park 2002; Chae et al. 2019). Some mountain ranges between the west and south subdistricts serve as strong long-term barriers to recurrent gene flow. Such barriers led to the split of *Coreoleuciscus splendidus* populations into two genetically discrete subdistrict populations (Kim et al. 2012). Geographical speciation has also been observed among some species of the Cyprinidae family on the Korean Peninsula (Kim 1997; Kim and Park 2002; Park and Kim 2010). Isolation of fish populations in different river systems has led to high levels of endemism in Korean *Liobagrus*, including *L. geumgangensis*.

Key to species of *Liobagrus* distributed in Korea

1 The length of both jaws is the same, and the mouth is in front of the snout ... **2**
– The length of both jaws is different, the lower jaw is shorter than the upper jaw, and the mouth is located below the snout ... **3**
2 The pectoral fin spines have 0–3, and the adults have small and traces ... ***L. andersoni***
– The spines of the pectoral fin are 3–5, and the spines of the adult are large and clear ... ***L. obesus***
3 There are no bright bands on the edges of the dorsal fin, anal fin, caudal fin, and adipose fins, while a crescent-shaped bright band appears in the center of the caudal fin ... ***L. somjinensis***
– The dorsal fin, anal fin, caudal fin, and adipose fin have bright colored bands, while there is no crescent-shaped bright band in the center of the caudal fin ... **4**
4 The edges of the anal fin, caudal fin, and adipose fin have a bright band. The pectoral fin spines are long (more than 7% of the standard length), and the dorsal fin spines are also long (more than 5% of the standard length) ... **5**
– There are narrow or almost no light-colored bands along the edges of the anal, caudal and adipose fins. The length of the pectoral fin spines is short (less than 6% of the standard length), and the length of the dorsal fin spines is also short (more than 4% of the standard length) ... ***L. hyeongsanensis***
5 A wide band of bright color appears on the edge of each fin, the number of rays of the pectoral fin is I, 7, and the distance between the origin of the pelvic fin and the origin of the anal fin is long (more than 17% of the standard length) ... ***L. mediadiposalis***
– There is a bright band at the edge of each fin, but the width is narrow. The number of rays of the pectoral fin is I, 8, and the distance between the origin of the pelvic fin and the origin of the anal fin is short (less than 15% of standard length) ... ***L. geumgangensis* sp. nov.**

Comparative material examined

Liobagrus andersoni: CNUC 9441–3, 3 specimens, 86.3–90.9 mm SL, Bongpyeong-myeon, Pyeongchang-gun, Gangwon-do, Han River, South Korea; CNUC 39021, 1 specimen, 71.5 mm SL, Cheongchen-myeon, Goesan-gun, Chungcheongbuk-do, Han River, South Korea. CNUC 38753–38778, 26 specimens,

81.4–105.5 mm SL, Gasoo-ri, Jeongseon-eup, Jeongseon-gun, Gangwon-do, Han River, South Korea.

Liobagrus obesus: CNUC 936–40, 5 specimens, 58.2–81.8 mm SL, Simcheon-myeon, Yeongdong-gun, Chungcheongbuk-do, Geum River, South Korea: CNUC 9434, 9436, 9439, 3 specimens, 82.3–94.8 mm SL, Simcheon-myeon, Yeongdong-gun, Chungcheongbuk-do, Geum River, South Korea: CNUC 39022, 1 specimen, 95.5 mm SL, Gosan-myeon, Gosan-gun, Jeollabuk-do, Mankyeong River, South Korea.

Liobagrus mediadiposalis: CNUC 37821–38, 18 specimens, 73.9–100.3 mm SL, Sicheon-myeon, Sancheong-gun, Gyeongsangnam-do, Nakdong River, South Korea: CNUC 1019–20, 2 specimens, 55.6–64.7 mm SL, Imgok-dong, Gwangsan-gu, Gwangju, Yeongsan River, South Korea: CNUC 1025–8, 4 specimens, 78.9–108.9 mm SL, Hamyang-gun, Gyeongsangnam-do, Nakdong River, South Korea: CNUC 1035–8, 4 specimens, 82.4–109.5 mm SL, Yurim-myeon, Hamyang-gun, Gyeongsangnam-do, Nakdong River, South Korea: CNUC 1801–5, 5 specimens, 83.4–107.8 mm SL, Macheon-myeon, Hamyang-gun, Gyeongsangnam-do, Nakdong River, South Korea: CNUC 1806–8, 3 specimens, 81.9–102.6 mm SL, Cheoncheon-myeon, Jangsu-gun, Jeollabuk-do, Geum River, South Korea: CNUC 1809, 1 specimen, 89.4 mm SL, Samcheok-si, Gangwon-do, Samcheokoship Stream, South Korea: CNUC 9445, 1 specimen, 123.7 mm SL, Mungyeong-eup, Mungyeong-si, Gyeongsangbuk-do, Nakdong River, South Korea: CNUC 39153, 1 specimen, 97.0 mm SL, Sicheon-myeon, Sancheong-gun, Gyeongsangnam-do, Nakdong River, South Korea.

Liobagrus somjinensis: CNUC 37749, 1 specimen, 99.4 mm SL, Geumji-myeon, Namwon-si, Jeollabuk-do, Somjin River, South Korea: 37750–65, 16 specimens, 74.1–100.6 mm SL, Geumji-myeon, Namwon-si, Jeollabuk-do, Somjin River, South Korea: CNUC 37766–9, 4 specimens, 74.8–91.3 mm SL, Jukgok-myon, Gokseong-gun, Jeollanam-do, Somjin River, South Korea: CNUC 39170, 1 specimen, 99.4 mm SL, Sikjeong-dong, Namwon-si, Jeollanam-do, Somjin River, South Korea.

L. hyeongsanensis: CNUC 38547, 1 specimen, 84.1 mm SL, Yangbuk-myeon, Gyeongju-si, Hyeongsan River, South Korea: CNUC 38548–38567, 20 specimens, 57.1–84.1 mm SL, Yangbuk-myeon, Gyeongju-si, Hyeongsan River, South Korea: CNUC 38830–38854, 25 specimens, 41.8–67.8 mm SL, Hwangnyong-dong, Gyeongju-si, Bukcheon River, South Korea.

L. geumgangensis (for gill raker analysis): CNUC 39138–39142, 39170–39184, 20 specimens, 60.2–95.7 mm SL, Namyang-myeon, Cheongyang-gun, Chungcheongbuk-do, Geum River, South Korea.

L. reini: CNUC 38971–38972, 2 specimens, 48.9–64.5 mm SL, Sanda, Hyogo Prefecture, Japan.

L. formosanus: NTHUB 01763, 7 specimens, 56.6–86.4 mm SL, Puli, Nantou County, Taiwan; NTHUB 01766, 1 specimen, 73.3 mm SL, Changhua County, Taiwan.

L. nigricauda: IHB 0110, IHB 0114, IHB 0366, IHB 0379, IHB 83135, IHB 920503, IHB 8840595, IHB 8841429, 13 specimens, 54.5–94.2 mm SL, Sichuan Province, China.

L. marginatoides: CAS 5224, CAS 5227, CAS 5230, CAS 5234, CAS 5332, 5 specimens, 51.8–58.6 mm SL, Sichuan Province, China.

L. styani: CAS 770020–4, 5 specimens, 52.0–95.3 mm SL, Shanxi Province, China; CAS 80-1317, CAS 80-0897, CAS 80-1204–5, CAS 90-0205, CAS 90-

0207, CAS 90-0209, CAS 81-1371, CAS 81-1373, 9 specimens, 67.5–101.5 mm SL, Jangxi Province, China.

L. marginatus: CAS 177637–177684, 48 specimens, 83.1–116.2 mm SL, Sichuan Province, China.

L. anguillicauda: CAS 131004–131039, 36 specimens, 87.9–98.6 mm SL, Anhui Province, China.

Acknowledgments

We thank Prof. H. T. Kim at Jeonju National University of Education, Jeonju, South Korea, and Mr. J. U. Kim at Jeonbuk National University, Jeonju, South Korea for collecting samples from several streams.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

No funding was reported.

Author contributions

Su-Hwan Kim and Seung-Woon Yun wrote the text and made the figures. Seung-Woon Yun and Jong Young Park edited and approved the manuscript for publication.

Author ORCIDs

Su-hwan Kim https://orcid.org/0000-0003-4831-5071
Seung-woon Yun https://orcid.org/0000-0003-0893-4468
Jong-young Park https://orcid.org/0000-0003-2348-5111

Data availability

All of the data that support the findings of this study are available in the main text.

References

Blyth E (1858) Report of Curator, Zoological Department, for May, 1858. Journal of the Asiatic Society of Bengal 27: 267–290.

Chae BS, Song HB, Park JY (2019) A Field Guide to the Freshwater Fishes of Korea. LG Evergreen Foundation, Seoul, 355 pp.

Chen XP, Lundberg JG (1995) *Xiurenbagrus*, a new genus of amblycipitid catfishes (Teleostei: Siluriformes), and phylogenetic relationships among the genera of Amblycipitidae. Copeia 4: 780–800.

Chen ZG, Wu JY, Wen AX (2021) *Liobagrus huaiheensis*, a new species of torrent catfish (Teleostei: Siluriformes: Amblycipitidae) from the Huaihe River basin in Central China. Zootaxa 4952(2): 391–400. https://doi.org/10.11646/zootaxa.4952.2.11

Chen ZG, Guo YS, Wu JY, Wen AX (2022) *Liobagrus chengduensis*, a new species of torrent catfish (Teleostei: Siluriformes: Amblycipitidae) from the upper Changjiang River basin in southwest China. Zoological Research 43(4): 679–682. https://doi.org/10.24272/j.issn.2095-8137.2022.114

Chough SK, Kwon ST, Ree JH, Choi DK (2000) Tectonic and sedimentary evolution of the Korean peninsula: A review and new view. Earth-Science Reviews 52: 175–235. https://doi.org/10.1016/S0012-8252(00)00029-5

Gűnther A (1892) List of the Species of Reptiles and Fishes Collected by Mr. A. E. Pratt on the Upper Yang-tze-kiang and in the Province Sze-Chuen, with Description of the New Species. Appendix II. London, Longmans, Green and Company, 238–350.

Hilgendorf FM (1878) Einige neue Japanische Fischgattungen. Sitzungsberichte der Gesselschaft Naturforschender Freundezu, Berlin, 404–457.

Hubbs CL, Lagler KF (1964) Fishes of the Great Lakes Region. University of Michigan Press, Ann Arbor, 213 pp.

Kim IS (1997) Illustrated Encyclopedia of Fauna and Flora of Korea Vol. 37 Freshwater Fishes. Ministry of Education, Seoul, 613 pp.

Kim SH (2013) Taxonomic revisions of the Genus *Liobagrus* (Siluriformes: Amblycipitidae) from Korea. Doctoral dissertation, Chonbuk National University, Jeonju, 125 pp.

Kim IS, Park JY (2002) Freshwater Fishes of Korea. Kyo-Hak Publishing Co., Ltd, Korea, 465 pp.

Kim IS, Park JY, Nalbant TT (2000) A new species of *Koreocobitis* from Korea with a redescription of *K. rotundicaudata*. Korean Journal of Ichthyology 12: 89–95.

Kim IS, Park JY, Son YM, Nalbant TT (2003) A review of the loaches, genus *Cobitis* (Teleostomi: Cobitidae) from Korea, with the description of a new species *Cobitis hankugensis*. Korean Journal of Ichthyology 15: 1–11.

Kim MJ, Han SH, Yang HY, Jo MR, Chung SC, Song CB (2006) Evolutionary relationship of *Liobagrus mediadiposalis* (Teleostei: Amblycipitidae) populations in Korea inferred from cytochrome b DNA sequences. Korean Journal of Ichthyology 18: 329–338.

Kim KY, Nam YK, Bang IC (2012) Phylogeny and divergence time estimation of *Coreoleuciscus splendidus* populations (Teleostei: Cypriniformes) endemic to Korea based on complete mitogenome sequences. Genes & Genomics 34: 149–156. https://doi.org/10.1007/s13258-011-0098-x

Kim SH, Kim HS, Park JY (2015) A new species of torrent catfish, *Liobagrus hyeongsanensis* (Teleostei: Siluriformes: Amblycipitidae), from Korea. Zootaxa 4007: 267–275. https://doi.org/10.11646/zootaxa.4007.2.9

Mori T (1935) Studies on the geographical distribution of freshwater fish in Korea. Nihon Seibutsu Chiri Gakkai Kaiho 7: 35–61.

Mori T (1936) Description on new genera and three new species of Silurioidea from Choseon. Zoological Magazine 48: 671–675.

Ng HH, Kottelat M (2000) A review of *Amblyceps* (Siluriformes: Amblycipitidae) in Indochina, with descriptions of five new species. Ichthyological Exploration of Freshwaters 11: 335–348.

Nguyen VH (2005) Ca Nuoc Ngot Viet Nam. Tap II [Freshwater Fishes of Vietnam (Vol. II)]. Nha Xuat Ban Nong Nghiep, Hanoi, 760 pp.

Nichols JT (1926) Some Chinese freshwater fishes. XVIII. New species in recent and earlier fukien collection. American Museum Novitates 169: 1–7.

Oshima M (1919) Contributions to the study of the freshwater fishes of Formosa. Annals of the Carnegie Museum 12: 169–328. https://doi.org/10.5962/p.34608

Park JY, Kim SH (2010) *Liobagrus somjinensis*, a new species of torrent catfish (Siluriformes: Amblycipitidae) from Korea. Ichthyological Exploration of Freshwaters 21: 345–352.

Regan CT (1904) On a collection of fishes made by Mr. J. Graham at Yunnan Fu. Annals and Magazine of Natural History (Ser.7) 13: 190–194. https://doi.org/10.1080/00222930408678897

Regan CT (1908a) Description of new fishes from Lake Candidius Formosa, collected by Dr. A. Moltrecht. Annals and Magazine of Natural History (Ser. 8) 10: 358–360. https://doi.org/10.1080/00222930808692494

Regan CT (1908b) Descriptions of new freshwater fishes from China and Japan. Annals and Magazine of Natural History (Ser. 8) 1: 149–153. https://doi.org/10.1080/00222930808692377

Regan CT (1908c) On freshwater fishes from Corea. Proceedings of the Zoological Society of London: 59–63. https://doi.org/10.1111/j.1096-3642.1908.tb01835.x

Sohn YK, Rhee CW, Shon H (2001) Revised stratigraphy and reinterpretation of the Miocene Pohang basinfill, SE Korea: Sequence development in response to tectonism and eustasy in a back-arc basin margin. Sedimentary Geology 143: 265–285. https://doi.org/10.1016/S0037-0738(01)00100-2

Son YM (1987) Systematic Studies on the Torrent Catfish, Family Amblycipitidae from Korea. Chung-ang Univ., Korea, 81 pp.

Son YM, Kim IS, Choo IY (1987) A new species of torrent catfish, *Liobagrus obesus* from Korea. Korean Journal of Limnology 20: 21–29.

Song HY, Bang IC (2015) *Coreoleuciscus aeruginos* (Teleostei: Cypriniformes: Cyprinidae), a new species from the Seomjin and Nakdong rivers, Korea. Zootaxa 3931(1): 140–150. https://doi.org/10.11646/zootaxa.3931.1.10

Sun ZW, Ren SJ, Zhang E (2013) *Liobagrus chenghaiensis*, a new species of catfish (Siluriformes: Amblycipitidae) from Yunnan, South China. Ichthyological Exploration of Freshwaters 23(4): 375–384.

Tchang TL (1935) A new catfish from Yunnan. Bulletin of the Fan Memorial Institute of Biology. Peiping 6: 95–97. [Zoological Series]

Vasil'eva ED, Kim DM, Vasil'ev VP, Ko MH, Won YJ (2016) *Cobitis nalbanti*, a new species of spined loach from South Korea, and redescription of *Cobitis lutheri* (Teleostei: Cobitidae). Zootaxa 4208(6): 577–591. https://doi.org/10.11646/zootaxa.4208.6.5

Wakiya T, Mori T (1929) On two new loaches of the genus *Cobitis* from Korea. Journal of the Chosen Natural History Society 9: 31–33.

Wright JJ, Ng HH (2008) A new species of *Liobagrus* (Siluriformes: Amblycipitidae) from Southern China. Proceedings. Academy of Natural Sciences of Philadelphia 157: 37–43. https://doi.org/10.1635/0097-3157(2008)157[37:ANSOLS]2.0.CO;2

Wu HW (1930) Description de poissons nouveaux de Chine. Bulletin du Muséum national d'Histoire naturelle (Ser. 2) 2: 255–259.

Xie RX, Zhang E (2018) Re-description of the catfish species *Liobagrus kingi* Tchang, 1935 (Pisces: Amblycipitidae) from the upper Chang-Jiang basin, China. Zootaxa 4476(1): 69–76. https://doi.org/10.11646/zootaxa.4476.1.6

Xie RX, Cao L, Zhang E (2022) *Liobagrus brevispina*, a new species of torrent catfish (Siluriformes: Amblycipitidae) from the upper Chang-Jiang basin, South China. Journal of Fish Biology 101(3): 478–490. https://doi.org/10.1111/jfb.15109

Zhao YH, Lan JJ, Zhang CG (2004) A new species of amblycipitid catfish, *Xiurenbagrus gigas* (Teleostei: Siluriformes), from Guangxi, China. Ichthyological Research 51: 228–232. https://doi.org/10.1007/s10228-004-0220-z